COMBINING GPS WITH TOA/TDOA OF CELLULAR SIGNALS TO LOCATE TERMINAL

TECHNICAL FIELD OF THE INVENTION

The present invention relates to global positioning satellite systems and cellular networks, and in particular, combining aspects of each technology in order to provide an efficient, reliable, and highly accurate position location system.

BACKGROUND OF THE INVENTION

The NAVSTAR (Navigation System with Time and Range) Global Positioning System (GPS) is a space-based radio-positioning and time-transfer system. While the system was originally developed primarily for military purposes, it now also contains a "coarse acquisition" (C/A) channel that is available for general civilian use. GPS provides accurate position, velocity, and time (PVT) information for a given object anywhere on the face of the earth, such as a moving mobile terminal in a vehicle. The NAVSTAR GPS includes three major system segments: (i) a space segment, (ii) a control segment, and (iii) a user segment. Briefly, the space segment has twenty four NAVSTAR satellites, each of which broadcasts radio frequency (RF) ranging codes and navigation data messages. Each navigation data message includes such data as satellite clock-bias data, ephemeris data (precise orbital data of the satellite), certain correction data, and satellite almanac data (coarse orbital data on the 24 satellites). The twenty four satellites are arranged in six orbital planes with four satellites in each plane, and the orbital planes are inclined at an angle of 55 degrees relative to the earth's equator. The control segment primarily consists of a master control station currently at Falcon Air Force Base in Colorado, along with monitor stations and ground antennas at various locations around the world. The master control station monitors and manages satellite constellation. The monitor stations passively track GPS satellites in view and collect ranging data for the satellites. This ranging data is transmitted to the master control system where satellite ephemeris and clock parameters are estimated and predicted. Furthermore, the master control system uses the ground antennas to periodically upload the ephemeris and clock data to each satellite for retransmission in the navigation data message. Finally, the user segment comprises GPS receivers, specially designed to receive, decode, and process the GPS satellite signals.

Generally, the satellites transmit ranging signals on two D-band frequencies: Link 1 (L1) at 1575.42 MHz and Link 2 (L2) at 1227.6 MHz. The satellite signals are transmitted using spread-spectrum techniques, employing ranging codes as spreading functions, a 1.023 MHz coarse acquisition code (C/A-code) on L1 and a 10.23 MHz precision code (P-code) on both L1 and L2. The C/A-code consists of a 1023 bit pseudorandom (PRN) code, and a different PRN code is assigned to each GPS satellite, as selected from a set of codes called Gold codes. The Gold codes are designed to minimize the probability that a receiver will mistake one code for another (i.e., minimize cross-correlation). The C/A-code is available for general civilian use, while the P-code is not. In addition, a 50 Hz navigation data message is superimposed on the C/A-code, and contains the data noted above.

In particular, the navigation message has 25 frames of data, each frame having 1,500 bits. Each frame is divided into five subframes of 300 bits each. At the 50 Hz transmission rate, it takes six seconds to receive a subframe, thirty seconds to receive one data frame, and 12.5 minutes to receive all twenty five frames. Subframes **1**, **2**, and **3** have the same data format for all twenty five frames. This allows the receiver to obtain critical satellite-specific data within thirty seconds. Subframe **1** contains the clock correction for the transmitting satellite, as well as parameters describing the accuracy and health of the broadcast signal. Subframes **2** and **3** contain ephemeris parameters. Finally, subframes **4** and **5** contain data common to all satellites and less critical for a receiver to acquire quickly, namely almanac data and low-precision clock corrections, along with other data.

The ranging codes broadcast by the satellites enable the GPS receiver to measure the transit time of the signals and thereby determine the range between the satellite and the receiver. It should be noted, however, that range measurements inherently contain an error called an offset bias common to all the measurements created by the unsynchronized operation of the satellite and the user's clocks. See U.S. Pat. No. 5,467,282 to Dennis. This user clock error will yield an erroneous range measurement, making it appear that the user is either closer to or farther from each of the satellites than is actually the case. These measurements are therefore more accurately termed pseudoranges. The navigation data messages enable the receiver to calculate the position of each satellite at the time the signals were transmitted.

In general, four GPS satellites must be in clear view of the GPS receiver in order for the receiver to accurately determine its location. The measurements from three GPS satellites allow the GPS receiver to calculate the three unknown parameters representing its three-dimensional position, while the fourth GPS satellite allows the GPS receiver to calculate the user clock error, and therefore determine a more precise time measurement. The GPS receiver compiles this information and determines its position using a series of simultaneous equations.

In addition, when the GPS receiver is first turned on, it must calculate its initial position. This initial determination is known as a "first fix" on location. Typically, the receiver must first determine which satellites are in clear view for tracking. If the receiver is able to immediately determine satellite visibility, the receiver will target a satellite and begin its acquisition process. If there is no almanac or position information already stored in the receiver, then the GPS receiver enters a "search the sky" operation that searches for satellites. Once the satellites are tracked, the receiver begins receiving the necessary data, as described above.

The "time-to-first-fix" (TTFF) represents the time required for a receiver to acquire the satellite signals and navigation data, and to calculate its initial position. If the receiver has no estimate of current time and position and a recent copy of almanac data, then this process generally takes about 12.5 minutes, which is the time necessary to receive a complete navigation data message assuming a 50 Hz transmission rate and receipt of twenty five frames of data, as described above.

A common problem with the conventional GPS is not having four GPS satellites in clear view of the GPS receiver. This commonly arises, for example, in a city setting such as in an urban canyon—i.e., in the shadow of a group of tall buildings—which can block the GPS satellite signals, or indoors in the buildings themselves. In such situations, the GPS receiver is unable to accurately determine its location using GPS.